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ontario hydro
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To Mr. D.G. Comissiong
Director of Marketing Operations

INDOOR AIR QUALITY
STATE-OF-THE-ART

J.B. Ciz

This state-of-the-art report presents the Ontario Hydro Research Division experience, and a review of the literature, on indoor [illegible]quality. Trends in energy conservation have [illegible]uraged reducing the air leakage of homes. This leads to the build up of indoor pollutants. There are a multitude of pollutants but the recognized major pollutants requiring immediate attention are carbon monoxide, nitrogen dioxide, formaldehyde and radon gas. Concern arises since many people spend 90% of their time indoors and little is known about the effects of long term, low level exposures on the health of humans.

INTRODUCTION

By request of the Residential Marketing Department, a project was undertaken to review the literature on indoor air quality published in the last few years. Older houses tended to leak air through cracks in the building envelope allowing pollutants created indoors to flush out relatively quickly. However, energy conservation measures encourage making homes tighter, thus causing a build-up of pollutants. This deterioration of indoor air quality is a concern because evidence indicates human health can be affected. At the present level of understanding, conditions in most Ontario homes are not considered serious.

As well as these long-term health effects, air-sealing also creates an immediate safety concern, viz the potential to backdraft combustion equipment.

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Indoor air quality received headlines when the Canadian Government banned the further use of Urea Formaldehyde Foam Insulation (already in 80 000 homes) during 1981. Subsequent research has shown that the major pollutants requiring immediate attention are carbon monoxide, nitrogen dioxide, formaldehyde and radon/1/. In addition, tobacco smoke and ozone are significant pollutants. The number of potentially hazardous pollutants is great, eg, tobacco smoke alone contains about 1200 compounds. A table of potentially harmful pollutants, their description and health effects is found in Appendix A.

Generally, residences with electric heating systems are less polluted than residences with gas equipment/2/. Formaldehyde and radon gas are the contaminants primarily relevant in electrically heated homes. Electric homes with fireplaces, wood stoves, or equipped with electric-oil heating systems may have the same pollutants as found in homes with combustion appliances.

Contaminant level standards are available for industrial, commercial and outdoor environments/14,19/, but none exist for residences where pollutant concentrations are relatively low level but exposures are for long durations. Current practice dictates that source control and controlled ventilation are the primary approaches for the maintenance of acceptable indoor air quality. Ventilation is extensively used in industrial and commercial environments, but not yet fully engineered for houses.

This report presents information on the state-of-the-art of indoor air quality. The field is evolving very rapidly and available research is not complete. The report highlights recent research and available literature. Recommendations are made for the Marketing Division and for further work by the Research Division.

1.0 INDOOR AIR QUALITY PROBLEMS

1.1 Human Susceptibility

Tightening the envelopes of houses beyond a certain point without attention to pollutant sources can lead to levels of contaminants which are dangerous to health. What is worse, a short-term overexposure to certain pollutants, for example formaldehyde, can trigger a continuing sensitivity to that pollutant which did not previously exist.

Some people are more susceptible than others to reduced indoor air quality and individual susceptibility varies over time. Segments of the population which are especially vulnerable include:

- very young
- very old
- pregnant women
- asthmatics

In Canada, about 1/3 of the population are considered as members of these high risk groups/1/.

Because no residential pollutant exposure standards exist, a Canadian intergovernmental working group is currently developing guidelines for controlling indoor air quality/13/. Little is known about the health effects from the long-term, low level exposure in homes. Combination reactions are possible between the numerous individual pollutants, and this makes assessment of indoor air quality even more difficult.

1.2 Pollutants

As concluded by Small/1/, the major pollutants requiring immediate attention are: carbon monoxide, nitrogen dioxide, formaldehyde, and radon gas (Radon-222 and Radon daughters). The currently permissible concentrations for 24 h residential occupancy are as follows:

TABLE 1

CONCENTRATIONS PERMISSIBLE FOR 24 HOUR RESIDENTIAL OCCUPANCY

Chemical Substance	Permissible Concentration
Carbon Monoxide (CO)	5 ppm*
Nitrogen Dioxide (NO_2)	0.3 ppm
Formaldehyde (HCHO)	0.1 ppm
Radon Gas/1/	0.02 WL**

* Parts Per Million ** Working Level

The permissible concentrations in Table 1 for CO, NO_2 and HCHO are 10% of industrial, occupational Threshold Limit Values (TLVs). The industrial situation is based on a standard eight hour exposure. The residential situation is different since a certain segment of the population (housewives, small children, etc) have essentially continuous exposure in residences. The 10% rule of thumb has been adopted by indoor air quality

researchers to give working values; these are not yet confirmed or standardized. The listed value for Radon gas was established for houses built on reclaimed land in Florida and for houses in four communities associated with uranium mining in Canada.

1.3 Carbon Monoxide, Nitrogen Dioxide etc

Indoors, the sources of carbon monoxide and nitrogen dioxide are from combustion appliances. Gas stoves, kerosene space heaters, wood stoves are major sources; faulty furnace systems (eg, blocked chimney, cracked heat exchanger etc), have been known to emit these gases into the indoor space. Carbon monoxide is a colourless, odourless and tasteless gas which affects the respiratory and circulatory system by interfering with oxygen transport. Mental performance is impaired and even death is possible. Nitrogen dioxide is a highly toxic and irritating gas. When inhaled, it passes into the lungs where it forms acid.

Wood burning in wood stoves and furnaces contributes to pollutants indoors. When these appliances are activated, suspended particulate concentrations increase about 3 times. More than 100 different chemicals have been identified in wood smoke. Typically, wood smoke has carbon monoxide levels 300 times and hydrocarbon levels 700 times those found in an oil furnace's flue gas. However, sulphur dioxide is only about 10% that of an oil furnace. A number of the compounds are known carcinogens/1/.

1.4 Formaldehyde

Formaldehyde is a chemical used in insulation materials, upholstery, particle board, plywood, textiles and adhesives. The emissions from Urea Formaldehyde Foam Insulation (UFFI) have been recognized as a threat to the health of the home occupants/17/. Corrective measures for homes containing UFFI are documented in References 17 and 18 . Additional assistance for UFFI problems is provided by the Federal Government's UFFI Centre. Sources other than UFFI may also be significant where modern building and furniture materials are extensively used (eg mobile homes). Excess humidity increases the emissions from formaldehyde sources. The reported health effects of formaldehyde gas are eye, nose and throat irritation, coughing and asthma-like symptoms, headaches, dizziness, nausea, vomiting and nose bleeds.

1.5 Radon

Radon (Rn-222) is itself a harmless, radioactive gas which has four daughter products: Polonium-218, Lead-214, Bismuth-214,

and Polonium-214. These four daughter products are active and will chemically or physically attach themselves to dust which is readily inhaled and may become lodged in the lungs/1/.

Soil, construction materials, and ground water are the major sources of indoor radon/14/. Hence, levels are usually higher in the basement. Concentrations found indoors are often 10 times that found outdoors. An effective means of limiting the ingress of Radon is to seal the joint between the basement floor and wall/12/.

McGregor et al/20/ measured radon and its daughters in about 10 000 homes in Canadian cities and found that average levels were well below the permissible concentration level for residences. They concluded that the levels of radon in Canada have only a small effect on lung cancer compared to the effects of smoking. Hollowell/reported in 1. p 16/ predicts that exposure to an average concentration of 1 pCi/L of radon (ie 1/200 WL of radon daughters at an equilibrium fraction of 0.5 with radon) would add a risk of 50 to 110 cases of lung cancer per million of population per year.

1.6 Tobacco Smoke

Tobacco smoke remains as a major pollutant; about 37% of adult Canadians smoke regularly/1/ and the rest are exposed (to various extents) to smoke released by others. About 1200 different compounds have been identified in the smoke/1/. Many of these are well documented as hazardous; a major one being formaldehyde. The amount of tobacco smoke found indoors can be very high, so that controlling it by ventilation alone may not be appropriate because of the high rates required. Solutions other than general ventilation may have to be found, for example, specially vented smoking areas, multi-speed ventilation systems, filtering etc.

1.7 Ozone

Ozone is a highly reactive and colourless gas detectable as an "electric" or "fresh air" smell at concentrations from 0.05 to 0.2 ppm/1/. Major sources are: intrusion from outdoor air pollution, UV light sources and electric arcs, such as occur in electronic air cleaners and motor brushes. Drier air increases arcing and therefore elevates ozone concentrations. Indoor ozone concentrations are generally lower than outdoor. Typically indoor levels are 0.001 to 0.020 ppm with peaks up to 0.120 ppm/4/. When operating properly an electric air cleaner will generate concentrations of 0.001 to 0.002 ppm. However, a defective unit or one requiring cleaning will generate up to 1 ppm/1/. At this level, the odour is disagreeable and similar

to sulphurous gas irritation. At this concentration, it may cause headaches and irritation in the throat/6/. The first alert level in Los Angeles is 0.05 ppm/1/.

2.0 CONTAMINANT CONTROL

2.1 Control by Ventilation

Controlled ventilation is the accepted way to control indoor air quality. To ensure proper operation of a controlled ventilation system, measures must be taken to airseal the house. This minimizes random leaks which circumvent the system's operation. Getting control over the house's ventilation also allows reduction of the resulting heat loss to just what is necessary. The use of a vapour retarder on the inside surfaces and proper air barriers on outside surfaces will allow gassing out of wall components and insulation outdoors, and at the same time prevent gases from entering the indoors. Step-by-step procedures for the design and installation of controlled ventilation systems in new houses are detailed in a draft handbook being developed for the National Home Builders' Association, (NHBA, formerly HUDAC)/10/. The basic requirements and design criteria are also applicable to existing houses, although the retrofit of the required ducting may present special problems. Before contemplating the retrofitting of a controlled ventilation system, consideration for upgrading existing bathroom and kitchen fans may prove to be more feasible.

ASHRAE Standard 62-1981 outlines the ventilation requirements for acceptable indoor air quality/9/. Briefly, ventilation for residences is suggested to be:

5 L/S per habitable room
+25 L/S per each bathroom, when used
+50 L/S per each kitchen, when used

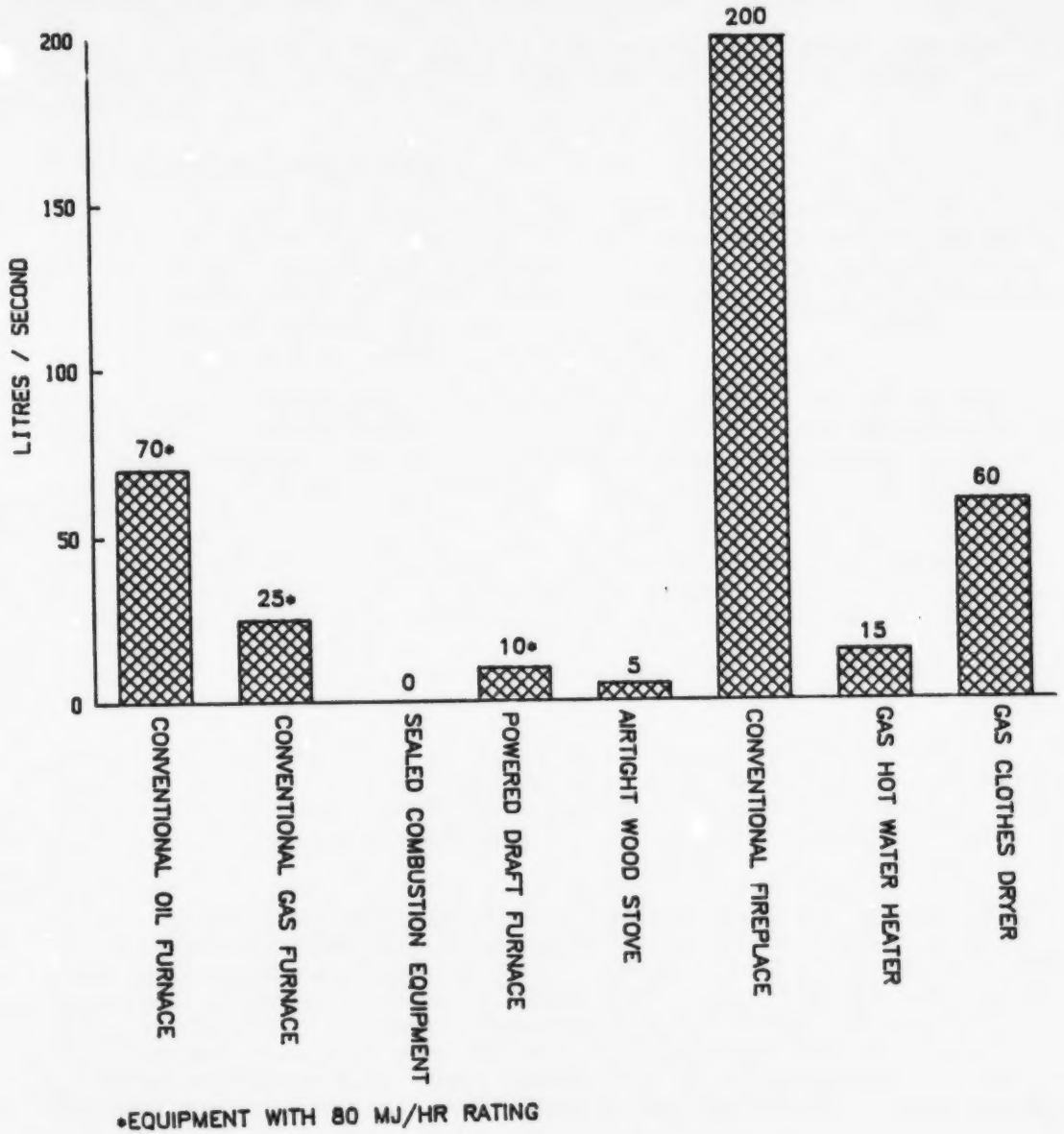
For example, for a 7 room house (living room, kitchen, dining room, 2 bedrooms, bathroom and family room) a continuous rate of 35 L/S (70 cfm) is specified, with extra capacity in the bathrooms and kitchen for intermittent use when required. The standard house occupancy is related to the number of rooms for simplicity of application.

Separate from the fresh air ventilation requirements of the home, any combustion appliances will need an extra supply of air. This should be isolated from ventilation air, eg, by ducting air from outside directly into the furnace room. Representative ventilation requirements for combustion appliances are shown in Figure 1. The figure illustrates the especially great consumption of fireplaces.

FIGURE 1

COMBUSTION AND DRAFT CONTROL

REQUIREMENTS OF VARIOUS TYPES OF COMBUSTION EQUIPMENT



•EQUIPMENT WITH 80 MJ/HR RATING

Source: IBI Group, Guidelines for the Design and Installation of Residential Controlled Ventilation Systems. Housing and Urban Development Association Canada. Discussion Draft. Toronto May 31, 1983.

In homes completely converted to electric heat from oil, permanently blocking the chimney stack could lead to serious condensation problems in the house/3,5/. The natural stack effect of the chimney yields continuous ventilation which aids the maintenance of air quality. Chimney exhaust air flows due to stack effect for an operating oil furnace and a house heated in part by electricity (eg, plenum heater) are estimated below:

TABLE 2

AIR FLOW IN THE CHIMNEY
OIL FURNACE VS ELECTRIC ONLY

	Oil Furnace Operating	Electric Heat Energized, Oil Furnace Not Operating/11, Eqn 10/
Chimney Air Flow	70 L/S	10 L/S

These values will vary depending on outdoor temperature, height of the chimney and furnace heat output. A chimney no longer required for the exhaust of combustion flue gases can be converted to a passive ventilation system with the addition of a damper (either manually or dehumidistat controlled). Further work is needed to investigate the use of chimneys in this way. There may be problems with the integrity of poorly constructed or maintained chimneys when used as ventilation exhaust devices.

Air-to-air heat exchangers (ATAHE) can be retrofitted for ventilation and heat recovery from exhaust air. Their primary purpose is to provide ventilation. A second benefit is heat recovery which is an energy conserving feature and helps pay for the capital cost of the unit. Currently, they are relatively expensive, and are only suitable for very tight houses. The economics of their installation in regular homes is under study. A CSA standard for their certification is currently being written.

An alternative heat recovery ventilation system is to use heat pump heat recovery from the air exhausted to outdoors. Such systems are more economically attractive then ATAHEs since they do not necessarily require an intake duct system (ie, they can be used in houses of more usual airtightness). However, equipment is just becoming commercially available/16/.

To prevent buildup of moisture, electric clothes dryers should exhaust directly outdoors and not into the living space or attic/7/, or even into air-to-air heat exchanger exhaust ducts. A specific air supply to the dryer may be required so as not to disturb the balance of the home ventilation system.

Table 3 summarizes the use of ventilation and other control strategies (discussed below) for several types of pollutants/4/.

2.2 Other Control Methods

Outdoor air may not always be suitable as "fresh" air to dilute indoor contaminants. Instead of ventilating it may be necessary to remove contaminating sources, modify the sources or filter contaminants from the air. Suppressing sources of pollutants and filtering indoor air may permit reducing ventilation requirements and therefore save energy.

Removal of contaminating sources is an obvious solution and is warranted in cases where concentration levels are excessive, but it is not always practical or economical where concentrations are medium to low, as usually exists in most residences. Some examples of source removal are: removing Urea Formaldehyde Foam Insulation from the wall cavity (and replacing it with a more benign insulating material), prohibiting indoor kerosene heaters, and designating non-smoking areas. Substitution of combustion appliances with electric equivalents falls into this category. Ultraviolet light is effective for deactivating bacteria, but will not remove them from the air stream. This controls biological effects but not mechanical "dust" effects.

Source modification is an alternative to source removal and includes such things as coating surfaces which are emitting lead (from paints), radon and formaldehyde. Details of source containment and substitutions are not comprehensively documented.

The filtration of air has been employed in large commercial, industrial and institutional environments, but is not widely used in residences because it is expensive to buy, install and operate. Removal of particulates and gases requires two separate process stages. Correspondingly, filters fall into two categories: ones for particulate contaminants and ones for gaseous contaminants. Many standards on the application of filters for industrial environments are available; literature on

TABLE 3

SUMMARY OF CONTROL STRATEGIES FOR SOURCES OF INDOOR AIR POLLUTANTS[a]

Pollutants	Source Modification		Ventilation			Pollutant Removal		Other
	Material Substitution	Containment	Local Exhaust	General Ventilation	Spot Ventilation	Particle Removal	Gas and Vapour Removal	
Radon and progeny	R	R	NR	R	NR	R	NR	--
Formaldehyde and other organic substances	R	R	NR	R	NR	NR	R	--
Asbestiform minerals and fibrous glass	R	R	NR	NR	NR	R	NR	--
Combustion products	R[b]	NR	R[c]	R	R[c]	R[d]	R[d]	--
Consumer products	R	R	NR	R	NR	R[d]	R[d]	--
Tobacco smoke	R	NR	NR	R	NR	R[d]	R[d]	--
Odors	NR	R	R[c]	R	R[c]	R[d]	R[d]	Masking (R)
Biologic agents (particles)	R	R	R	R	R	R	NR	UV disinfection (R)
Carbon dioxide	NR	NR	R	R	R	NR	NR	--
Moisture	NR	NR	R	R	R	NR	R	--
Thermal extremes	R	R	R	R	R	NR	R	--

[a]R = recommended; NR = not recommended.
[b]Source of heating can be substituted (eg, heat pump, electric range).
[c]Usually combined strategies for a given pollutant.
[d]Both cleaning methods usually required.
Source: National Research Council, Indoor Pollutants. Washington DC, 1981

residential applications is rare. Particulate filters are rated as low (eg fiberglass furnace filters), medium or high efficiency (eg paper or fabric types). Electrostatic filters have efficiencies similar to medium and high efficiency mechanical filters. Their advantage is a low air pressure drop, commonly 10 times less than mechanical types/4/. The gas removal stage can be accomplished by filtration through a bed of activated carbon or charcoal material. Small electrostatic precipitators, generators, air filters and charcoal filters are advertised to promote particle-free and odour-free indoor air. Basic tests on small table-top air cleaners have shown them to be only marginally effective/21/. Efficiencies of these devices have not yet been fully evaluated by independent organizations. Better air cleaning is possible with a central electrostatic air cleaning unit.

3.0 DIAGNOSTICS

3.1 Measuring Contaminant Concentrations

The main difficulty in assessing indoor air quality is that it concerns a multitude of separate contaminants. Thus, a universal or surrogate indicator (eg, carbon dioxide) is not appropriate. To compound the difficulty, combinations of contaminants may create synergistic reactions, ie effects greater than the sum of the individual effects. Condensation is a partial indicator as it is associated with air tightness which leads to elevated contaminant concentrations. Nonetheless, it has limitations since it fluctuates with outdoor temperatures and living habits, which are not necessarily related to indoor air quality.

The sense of smell is not very reliable for detecting specific contaminants since many are odourless. Persistent odours from smoking, cooking etc, do, however, indicate lack of ventilation.

Devices for measuring the very low levels of many gases are available. Generally they are laboratory-based, relatively expensive and only measure a single gas or a small number of related gases.

An apparatus which may be employed by trained field personnel consists of gas-detecting tubes and a hand operated pump (piston or bellows type) to pass an air sample through the tube. The piston type is shown in Figure 2/23/. Operation is very simple. A gas detector tube selected for the subject gas is inserted into the pump. Sample air is drawn through the tube and the concentration of the gas is indicated as a colour change on a scale. This equipment is useful for field studies, being portable and giving an immediate indication of contaminant level. Drawbacks include needing a separate tube for each

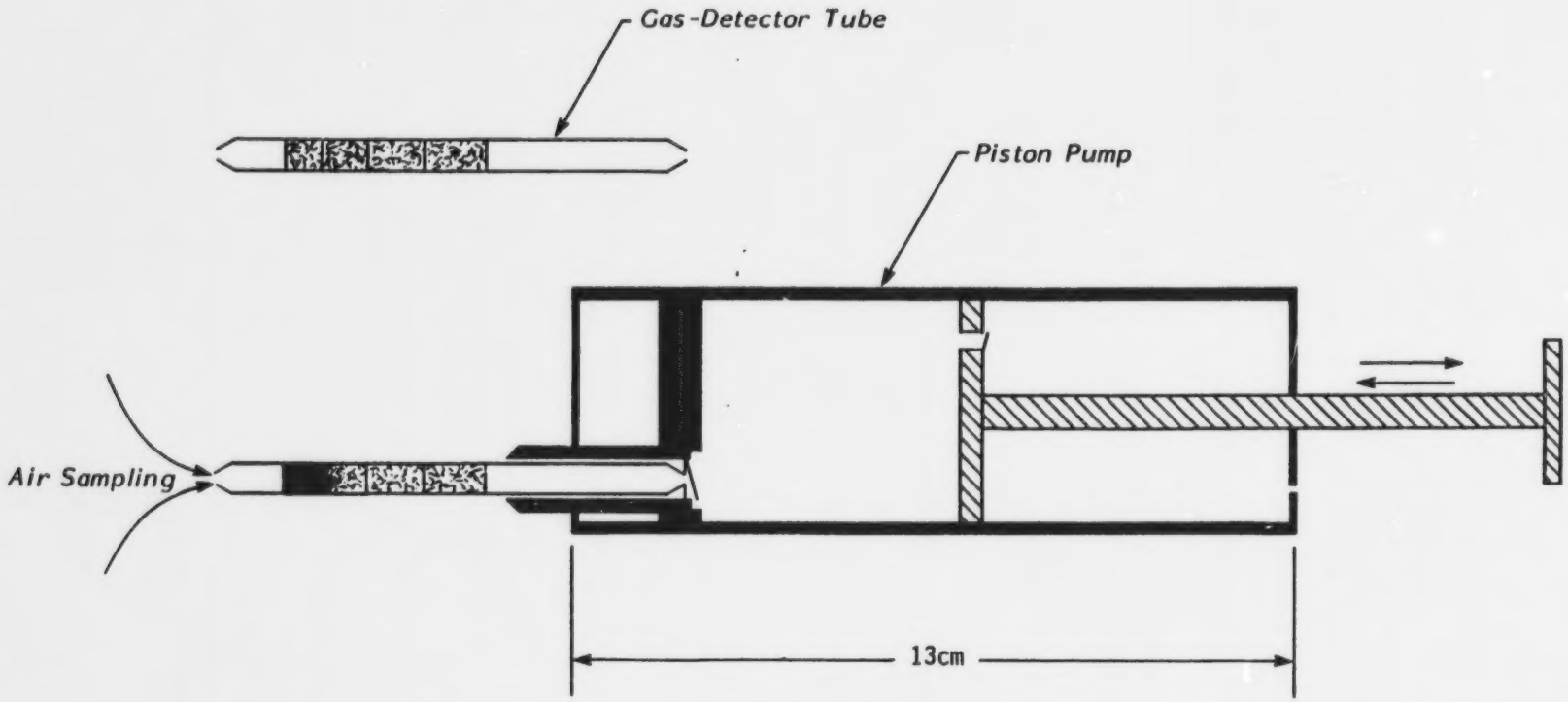


FIGURE 2
APPARATUS FOR GAS POLLUTANT DETECTION

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sample and for each contaminant of interest. Also, the sensitivity of the indication is geared to industrial applications (TLVs) and so is barely able to distinguish between acceptable and unacceptable levels for residential exposures. This latter problem may be corrected as the needs of the residential sector increase, and the manufacturers develop tubes with more appropriate sensitivities.

3.2 Measuring Ventilation

Various techniques are available to measure the natural ventilation rate, the house airtightness and to check on the operation of mechanical ventilation systems. A well recognized method of measuring the airtightness of the house envelope is by fan depressurization. The technique involves temporarily installing a powerful fan which discharges indoor air through an open doorway or window. The fan is operated at various speeds and the flow rates and the corresponding induced pressure drops across the envelope are measured. From the data one can determine the equivalent leakage area of the envelope. This test is useful as an indicator of how big the leaks are (and where they are located). The operating conditions of the test are artificial and so the results are not representative of natural infiltration. Work is being done to characterize whether houses are "too tight" and require mechanical ventilation, based on this relatively simple test. A list of fan suppliers is presented in Appendix B.

Another method, the tracer gas technique, involves injecting a small amount of a gas, mixing it throughout the house and noting the decay of its concentration in time. The test gives a direct measure of the air infiltration rate corresponding to the weather conditions prevailing at the time of the test. This gives an indication of the natural ventilation rate available to dilute contaminants.

The two most used tracer gases are nitrous oxide (N_2O) and sulphur hexafluoride (SF_6). The former is readily available, inexpensive and regarded as safe at low concentrations (typically 100 ppm). The latter is useful because it can be detected at concentrations as low as a few parts per billion. However, refrigerants leaking from air conditioners or refrigerators can influence SF_6 measurements and therefore affect results. Thorough mixing of the tracer gas is an important requirement/8/. Different tracer gas methods are available to do either spot measurements (1-2 h test) or time averaged, long term measurements (several months).

In assessing the effectiveness of mechanical ventilation systems (either the existing warm air distribution system or a dedicated ventilation system) the air distribution should be checked to

see if adequate air is being delivered to individual rooms. Balancing the duct system involves measuring air temperatures, air pressures and air velocities. Guidelines for balancing forced air heating systems are described in Reference 15. The work is best carried out by trained personnel. Reference 10 includes testing procedures for controlled ventilation systems.

4.0 CONCLUSIONS

1. Electrically-heated houses exhibit better indoor air quality than those heated with fossil fuels.

2. Retrofit air-sealing of houses normally won't create indoor air quality problems, but can if very extensive tightening is done or unusual sources exist.

3. New tighter construction and increased pollution sources in modern houses indicate a possible deterioration in indoor air quality in the future.

4. Contaminant control includes ventilation, source removal or modification, and filtering.

5. Simple indicators of pollutant levels (eg, relative humidity) are not reliable.

5.0 RECOMMENDATIONS

1. Because little is known about the effects of low level, long term contaminant exposure and because ventilation and air quality standards are undergoing development, technical currency in indoor air quality, especially as it pertains to electrically heated residences in Ontario, must be maintained.

2. Diagnostic devices and procedures for field use by Hydro personnel in assessing possible residential air quality problems need to be developed.

3. Solutions to residential air quality problems need to be developed and field tested.

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REFERENCES

1. Small, B.M. and Associates. Indoor Air Pollution and Housing Technology. CMHC Research Report. Ottawa, Ontario. August 1983.

2. Geomet Inc., Comparison of Indoor and Outdoor Air Quality. EPRI Report No EA-1733. Palo Alto, California, March 1981.

3. Ciz, J.B. Condensation State-of-the-Art. Ontario Hydro Research Report No 84-166-K. Toronto, Ontario. 1984.

4. National Research Council, Indoor Pollutants. Washington, D.C. 1981.

5. Ciz, J.B. Condensation Problems in Two Houses Converted to Electric Heating. Ontario Hydro Research Report No 82-340-K. Toronto, Ontario. July 20, 1982.

6. Stricker, S. Ventilation State-of-the Art. CEA Report No 918-U-50A. Montreal, Quebec. June 1980.

7. CMHC, Condensation in the Home: "Where, Why and What to Do About It". Ottawa, Ontario, 1982.

8. International Energy Agency, Techniques and Instrumentation for the Measurement of Air Infiltration in Buildings - a Brief Overview and Annotated Bibliography. Air Infiltration Centre. Berkshire, Great Britain. May 1983.

9. ASHRAE, Ventilation for Acceptable Indoor Air Quality. ASHRAE Standard 62-1981. Atlanta, Georgia. 1981.

10. IBI Group, Guidelines for the Design and Installaton of Residential Controlled Ventilation Systems. Housing and Urban Development Assocation Canada. Discussion Draft. Toronto. May 31, 1983.

11. ASHRAE, 1981 Fundamentals Handbook, American Society of Heating, Refrigerating and Air Conditionining Engineers. Atlanta, Georgia, 1981.

12. DSMA/ACRES, Evaluation of Radon and Air Quality Control Techniques. Report prepared by DSMA Atcon Ltd and ACRES Consulting Services Ltd for the The Ontario Ministry of Municipal Affairs, The Ontario Ministry of Energy, Rio Algom Ltd and Denison Mines Ltd. Toronto, Ontario. March 1984.

13. Meek, B. Health and Welfare - Canada. Personal Communication May 7, 1984.

14. American Conference of Governmental Industrial Hygienists. Threshold Limit Values for Chemical Substances in the Work Environment Adopted by ACGIH for 1983-84. Cincinatti, Ohio. 1983.

15. Heating, Refrigerating and Air-Conditioning Institute of Canada, Balancing Air Conditioning Systems (Residential). [Manual] - Islington, Ontario. January 1980.

16. Mills, B.E. State-of-the-Art Survey of the Use of Heat Pump Recovery Devices for Space Heating. Ontario Hydro Research Report No 84-10-K. Toronto, Ontario, February 27, 1984.

17. Chown et al. Urea Formaldehyde Foam Insulation Building Practice Note No 19, Division of Building Research, National Research Council. Ottawa, Ontario. April 1981.

18. Bowen et al. Urea Formaldehyde Foam Insulation: Problem Indentification and Remedial Measures For Wood-Frame Construction. Building Practice Note No 23, Divison of Building Research, National Research Council Canada. Ottawa, Ontario. April 1981.

19. NIOSH, Occupational Health Guidelines for Chemical Hazards. National Institute for Occupational Safety and Health, ODHS (NIOSH) Publication No 81-123. Washington, DC, January 1981.

20. McGregor, R.G. et al. Background Concentrations of Radon and Radon Daughters in Canadian Homes. Health Physics, Vol 39. Pergamon Press Ltd, USA, August 1980.

21. Canadian Consumer. Fan-Filter Air Cleaners, Consumers Association of Canada. Vol 14. No 5. Ottawa, Ontario. May 1984.

22. Canadian Consumer. Indoor Air Quality. Consumers Association of Canada. Vol 14. No 6. Ottawa, Ontario. June 1984.

23. Gastec. Blue Book - Precision Gas Detector System. Gastec Corporation. Tokyo, Japan. 1984.

BIBLIOGRAPHY

1. ASHRAE, 1979 Equipment Handbook, American Society of Heating, Refrigerating and Air Conditioning Engineers. Atlanta, Georgia, 1979.

2. EPRI Journal, Indoor Air Pollution p 50, Electric Power Research Institute. Palo Alto, California. May 1983.

3. Globe and Mail, Government Studies Guidelines on Indoor Air Quality in Houses. Toronto, Ontario. September 1, 1981.

4. New York Times, Dangers of Indoor Air Pollution. New York, NY January 28, 1981.

5. Globe and Mail, Carbon Monoxide Fumes: Toronto, Ontario. March 30, 1983.

6. Chown, G.A., Bowen, R.P., Shirtliffe, C.J., Urea Formaldehyde Foam Insulation. Division of Building Research, Building Practice Note No 19. Ottawa, Ontario, April 1981.

7. Safety Supply Canada, Safety Equipment Catalogue No 81, page GD4. Toronto, Ontario 1981.

8. HUDAC, Field Evaluation of Residential Ventilation Systems Guidelines. HUDAC Task Force on Airtightness, Controlled Ventilation and Heat Recovery. Toronto, Ontario, August 17, 1983.

9. Globe and Mail. In Search of Clean Air: Toronto, Ontario. May 5, 1984.

10. Eyre, D. How to Solve Backdrafting Problems and Air Quality Problems in Sealed Houses. Saskatchewan Research Council. SRC Publication No R-825-8-E-84. Saskatoon, Saskatchewan. March 1984.

APPENDIX A

POLLUTANTS/22/

Source: Canadian Consumer. Indoor Air Quality. Consumers Association of Canada. Vol 14. No. 6. Ottawa, Ontario. June 1984.

Pollutant	Descriptive Summary	Health Effects
Aerosols	Many consumer products yield high pollutant concentrations, which could present serious health hazards. Persons with cardiovascular or pulmonary impairment are at greatest risk.	Reduces tracheal mucus velocity and impairs airway defence mechanisms. No data on long-term use. Complaints of headaches, nausea shortness of breath, eye irritation, skin rashes, lung inflammation, liver damage, and cardiac arrhythmia have been attributed to normal aerosol use.
Ammonia	Often present in indoor air in small quantities and is known to irritate those susceptible. Little data available on incidence or health effects at low levels.	Inhaled ammonia is an irritant that primarily affects the upper respiratory tract. If ammonia concentrations are high or exposure prolonged, the eyes may be seriously damaged.
Asbestos	Potential sources include many products no longer produced but still present in many homes. Fibres are carcinogenic.	Mesothelioma, a rare form of cancer, believed to result only from the inhalation of asbestos fibres. Asbestosis may precede mesothelioma. Unexplained breathlessness and productive cough, accompanied by pain and tightness in the chest, may precede the disease by many years. Bronchogenic carcinomas, lung cancer, and cancer of the intestinal tract may also result from asbestos exposure.
Bacteria/Virus	Bacteria may grow in warm standing water (in humidifiers, for example). Transmission of infection by bacteria and virus increases with reduced ventilation.	Bacteria and viruses can produce infection, disease and allergic reactions. Respiratory viruses can be transmitted from person to person.

POLLUTANTS/22/ (cont'd)

Pollutant	Descriptive Summary	Health Effects
Carbon Dioxide	Indoor concentrations are often much greater than outdoor concentrations. Unvented kerosene heaters may produce concentrations well in excess of occupational standards.	Long-term exposure may cause changes in the acid balance if exposures exceed 5000 ppm. Concentrations at 50 000 ppm (5%) carbon dioxide in the air cause dizziness, headache and confusion. At 8-10%, severe headaches, dim vision, tremors and even unconsciousness will occur if the level is maintained for 10 minutes. Concentrations of 25-30% have been associated with diminished respiration, hypotension, coma, loss of reflexes and sense of touch. At these concentrations, consciousness is lost almost immediately and death may ensue.
Carbon Monoxide	Major sources are gas stoves, fossil fuels, furnaces and heaters. Exposure is widespread and often at levels above outdoor standards. Faulty furnaces have given rise to fatal carbon monoxide concentrations.	A low concentrations, shortness of breath on moderate exertion and slight headaches are reported. At higher concentrations symptoms include severe headaches, mental confusion, dizziness, impairment of vision and hearing, collapse or fainting on exertion. At extreme concentrations unconscious ness or death occurs.
Chlorine	Present in the home particularly in laundry preparations and in municipal water. Chemically susceptible people are known to be affected adversely but no data are available on indoor concentrations or long-term health effects.	Affects the mucosa of the eyes and the upper respiratory tract. Headaches, irritation of nasal sinuses, sneezing, coughing, loss of voice, dizziness, anxiety, unconsciousness, profuse tearing, and sensitivity to light have been reported.

POLLUTANTS/22/ (cont'd)

Pollutant	Descriptive Summary	Health Effects
Formaldehyde	Major sources include building materials and furnishings. Exposure can lead to generalized chemical susceptibility. Suspected to be a carcinogen.	Reported health effects include skin, eye and throat irritation, respiratory disorders and allergies, and a decreased threshold of reactivity with prolonged exposure. High exposure levels have produced nasal cancer in rats. Principal effect of the other aldehydes is irritation of the eyes and skin.
Fungi (Mould)	Universally present in homes but may grow significantly if there are sources of dampness. Moulds contain potent allergenic compounds and can affect health adversely.	Produces respiratory disease by precipitating allergic reaction in the respiratory tract. More rarely produces pulmonary infections.
House Dust	Covers a wide variety of compounds and mites that can be allergenic and therefore may adversely affect the health of a significant proportion of the population. A reasonable degree of avoidance for affected persons is feasible and recommended.	Contains allergenic compounds that may initiate and provide immunologically hypersensitive reactions. Depending on the nature of the dust, responses may be due to irritation or may be immunological.
Nitrogen Oxides	Tobacco smoking and indoor combustion are the major sources. Increased incidence of illness has been correlated with elevated NO_2 and other pollutant levels in the home.	Known to cause burning and choking sensations in the upper respiratory tract at concentrations of 25 to 75 ppm. Prolonged exposure will cause oxidization of hemoglobin and more severe symptoms such as sleepiness, feelings of intoxication and loss of consciousness. Nitrogen dioxide may cause lung damage by corroding the mucous lining of the lung.

POLLUTANTS/22/ (cont'd)

Pollutant	Descriptive Summary	Health Effects
Organic Vapours	Indoor air often contains low levels of complex mixes of organic vapours which, in combination, exceed outdoor and other standards. Many compounds present have detrimental effects at high concentrations and are known to affect hypersusceptible persons at levels commonly found in homes.	Little is known about the short- and long-term effect of many of the organic compounds found at low levels in residential environments. The health effects differ with each organic compound and range from respiratory irritation to being suspected carcinogens.
Ozone	Improperly maintained electrostatic air filters can produce ozone at levels above outdoor ambient standards. Persons already hyper-reactive are at greatest risk.	Irritation of the mucous membranes of the upper respiratory tract. Decrease in visual acuity and other changes in occular parameters. Laboratory animals experience increased death rates, sphering of red blood cells, structural changes in the nuclei of myocardial tissue, increased neo-natal death rate.
Pesticides	Widely used outdoors. Measurable concentrations found in human blood and tissue. Numerous incidents of illness have been reported and pesticides are suspected to be potent sensitizers that can lead to a more widespread chemical susceptibility.	Mild toxicity characterized by headache, dizziness, numbness and weakness of the extremities, apprehension and irritability. When large amounts are absorbed, symptoms may include muscular tremors, loss of balance, and convulsions. Death is usually due to cardiac failure or respiratory collapse.
Radon/Radon Decay Products	Present in most homes and may present a measurable cancer risk. Concentrations are greatest in energy-efficient homes with reduced ventilation.	Exposure to radon and its progeny at high concentrations causes lung cancer. Risk is directly proportional to dose.

Pollutant	Descriptive Summary	Health Effects
Sulphur Dioxide	Indoor concentrations often lower than those outside due to absorption on building surfaces. Fossil fuel combustion is the primary indoor source.	Irritation of the upper respiratory tract. Acute exposure above 20 ppm produces choking and sneezing. Direct effect of the epithelial tissue of the lung is presumed to be the predominant hazard.
Suspended Particles	Various household materials and activities in addition to smoking produce suspended particulates. Some particulates can cause irritation and lung disease. More research is needed, particularly concerning possible carcinogens.	Mineral, wool, and glass fibres, silica dust, organic dust, and chemicals absorbed in them can irritate the mucous membranes of the digestive and upper respiratory tract as well as the skin and eyes.
Tobacco Smoke	Tobacco smoke is the major source of inhaled suspended indoor particulates, producing concentrations well in excess of outdoor air standards. Contains known and potent carcinogens.	Primary effects at low concentrations are coughing, headache, nausea, and irritation of the eyes, nose, and throat. A number of polynuclear aromatic hydocarbons in tobacco have been identified as active tumorigenic agents. Tobacco smoke also interacts with asbestos exposure, increasing the cancer risk.

APPENDIX B

SUPPLIER OF FANS FOR DEPRESSURIZATION TESTS

Enercorp	2 Donald Street Winnipeg, Manitoba R3L 0K5 Tel: (204) 477-1283
Infiltec	P.O. Box 1533 Falls Church, Va 22041 Tel: (703) 820-7696
Retrotec	255 St. Anne Ave Ottawa, Ontario K1L 7C3 Tel: (613) 745-1515